MATERIALS BUREAU

TECHNICAL REPORT 89-5

# FIELD EVALUATION TROXLER MODEL 4640 THIN LIFT NUCLEAR DENSITY GAUGE



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NEW YORK STATE DEPARTMENT OF TRANSPORTATION

MARIO M. CUOMO, Governor FRANKLIN E. WHITE, Commissioner

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## FIELD EVALUATION
## TROXLER MODEL 4640
## THIN LIFT NUCLEAR DENSITY GAUGE


Prepared by

James P. Reidy P.E.
Civil Engineer II (Materials Bureau)


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MATERIALS BUREAU
JAMES J. MURPHY, DIRECTOR

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
1220 WASHINGTON AVENUE, ALBANY, NEW YORK 12232

ABSTRACT

The use of nuclear density gauges to monitor asphalt concrete pavement densities is a method currently being used in some states. Many potential advantages exist to using the gauge over conventional coring and testing methods. Advantages include; fast results, testing frequencies can be increased, and readings can be taken when the pavement is still hot and can be compacted further. One of the main questions regarding the use of nuclear density gauges is their accuracy. Past experience with gauges, used by the Materials Bureau to measure pavement densities, has shown a poor correlation between core and gauge densities. The following report details the field evaluation of a Troxler Model 4640 Nuclear Density Gauge. This evaluation was undertaken by the Materials Bureau in an effort to stay current with new developments in the field of pavement density monitoring equipment.

**INTRODUCTION:**

Typically, nuclear density gauges used to measure asphalt concrete pavement densities are operated in the backscatter mode. When operating in the backscatter mode conventional gauges have no way of limiting the depth to which they read. If the density of a thin, 1" - 1.5", asphalt concrete layer is to be determined accurately the density of the underlying material must somehow be accounted for. Troxler claims to have eliminated the need for this with the development of the Troxler Model 4640 Thin Lift Nuclear Density Gauge. This gauge operates in the backscatter mode only and has a variable depth setting. This allows the gauge to read densities on the top 1" - 2.5" of material only. For pavement layer thicknesses of 1" or more this eliminates the need for determining the density of the underlying material.

In studies conducted by other agencies the Troxler 4640 has provided results which correlated very well with core densities. In one such study the City of Greensboro, N.C. obtained an average variation between core and gauge densities of 0.5 (PCF) on 18 cores which were tested. Another study conducted by the Vermont DOT showed an average variation of 0.6 (PCF) on 8 cores which were tested. In both studies densities were determined on surface course material 1.5" thick.

SURVEY RESULTS:

In 1988 several states were polled as to their use of nuclear density gauges in monitoring asphalt concrete compaction. Agencies which had tried the Troxler Thin Lift Gauge had mixed feelings about its accuracy. Some obtained good results using the gauge. Others felt it was no more accurate than the gauges they were currently using which have no depth control capabilities. Most of the agencies polled do not use gauges to monitor densities on pavement layers less than 1.5" thick. On thinner lifts gauges are used primarily to establish rolling patterns which produce maximum pavement densities.

**PROJECT DESCRIPTION:**

On June 27 and 28, 1988 personnel from the NYSDOT Materials Bureau had an opportunity to evaluate the performance of a Troxler 4640 Thin Lift Nuclear Density Gauge. Testing was done on the Cohoes Waterford Arterial Project, Route 787, in Saratoga County. The project involved construction of a new full depth asphalt concrete pavement consisting of 5.5" of Type 1 Base, 1.5" of Type 3 Dense Binder, and 1.5" of Type 6F Top. Material was supplied by Pallette Stone Corp. of Saratoga Springs. This project incorporated a special specification for air void controlled construction. The spec. requires that cores be taken from the surface course and be analyzed for air void content. One core is taken from each 1500 lane feet of surface course paved. The maximum acceptable air void content, per this specification, is 7.0%. There is no minimum air void content per this specification.

**PROJECT TESTING:**

Prior to paving the surface course, core locations were laid out, one per each 1500 lane feet of pavement. Density readings, using the Thin Lift Gauge, were taken on the compacted top course material only. Four 1 minute gauge readings were taken at each core location after all rolling had been completed. The gauge was centered over the core location and was rotated 90 degrees about its center after each reading was taken. The gauge was set to read densities on the top 1.5" of material only; 1.5" being the design thickness of the Type 6F surface course. Actual core thicknesses varied from 7/8" to 1 5/8" thick. A total of twelve 6" diameter cores were taken, 9 from the first days paving and 3 from the second days paving. All coring was completed prior to the pavement being opened to traffic. The nuclear density gauge and the pavement coring equipment were both supplied and operated by the contractor's technician. Core air void analysis was done by the Region 1 Materials Lab. Gauge and core data has been compiled in Table I.

## RESULTS:

Densities obtained with the Troxler 4640 Thin Lift Gauge on this project did not show a good correlation with the core densities (See Table I and Graph I). The gauge showed an average density for the 12 test locations of 143.7 (PCF). The average density for the 12 cores was 147.4 (PCF), a difference of 3.7 (PCF). Based on manufacturer's specifications for the Troxler 4640 the degree of accuracy for a 1 minute reading, with the gauge set to read 1.5" deep, should be ±1.9 (PCF). The results from this study showed an error of almost twice this amount. While the gauge was set to read 1.5" deep there were 5 core locations where the surface course was less than 1.5" thick. If just the 7 cores which were 1.5" thick or greater are considered the average gauge density was 144.2 (PCF) and the average core density was 147.6 (PCF), a difference of 3.4 (PCF). The air void results show a similar correlation. Based on 7.0% being the maximum acceptable air void content the gauge indicated that only 2 of the 12 locations had acceptable air void contents. The core analysis showed that 10 of the 12 locations had acceptable air voids. (See Graph II)

One approach that can be used when initial testing indicates a poor correlation between the gauge and the core densities is to establish a correction factor. The correction factor is found by dividing the average core density by the average

gauge density. All subsequent gauge densities are then multiplied by the correction factor to get a corrected gauge density. Using the first 5 test locations on this project to establish a correction factor results in a correction factor of 1.017. When this correction factor is applied to the 12 gauge densities the average corrected gauge density becomes 146.2 (PCF), 1.2 (PCF) less than the average core density.

The repeatability of the gauge was also tested. Three core locations which were tested on the first day were checked again with the gauge on the second day. The same procedure of taking 4 readings per test and averaging them was used. Based on these 3 tests the repeatability of the gauge was good. The first days average density for the 3 locations was 144.2 (PCF). The second days average density was 145.2 (PCF), a difference of 1.0 (PCF). (See Table II)

## CONCLUSION:

The Troxler 4640 Thin Lift Nuclear Density Gauge was easy to operate and provided quick pavement density results. The four 1 minute gauge readings at each core location could be taken and averaged in as little as 5 minutes. Taking the pavement densities while the mat is still hot provides an opportunity for further compaction should the density readings be low. Using the gauge also increases the number of tests which can be run. This provides a more representative sample of the overall pavement density. On this project however the disadvantages of using the gauge outweighed the advantages. Based on the gauge readings only 2 out of the 12 test locations would have had acceptable compaction / air voids. The gauge densities were neither consistently higher nor consistently lower than the core densities. The variation ranged from -0.7 (PCF) to +9.8 (PCF).

The problem with the accuracy of the gauge seems to lie in the thickness of the pavement section being tested. On thicker pavement sections nuclear density gauges have shown good correlation with pavement core densities. In 1988 the department used a Troxler Model 3440 to monitor pavement densities on the Cross Bronx Expressway Project in New York City. The project consisted of placing one 2.5" thick lift of dense graded asphalt concrete over an existing PCC pavement. The average density for 20 cores which were taken was 153.6

(PCF). The average gauge density for the same 20 locations was 153.9 (PCF), a difference of 0.3 (PCF). (See Graph III) Of the asphalt concrete layers in a typical pavement section; base, binder and surface course; New York State considers proper compaction of the surface course to have the greatest influence on pavement performance. Currently much of the departments work involves overlays of existing pavements. The typical surface course thickness on an overlay ranges from 1" to 1.5". Keeping this in mind, the Department's current needs are for a nuclear density gauge which can provide accurate pavement densities on asphalt concrete layers from 1" to 1.5" thick. Based on the results from this project the Troxler Model 4640 does not provide density results with the degree of accuracy required for this type of work. One possible way to improve the accuracy of the gauge is by applying a correction factor to the gauge densities. However it must first be shown that the use of a correction factor will consistently improve the accuracy of the gauge. If this can be shown then the nuclear density gauge could be used as an effective tool to monitor pavement densities.

RECOMMENDATIONS:

1) Because of the potential advantages of using the nuclear gauge to monitor pavement densities further investigations should be made into its use. An air void controlled job where cores are being taken routinely would make a good candidate for testing.

2) The next time that a gauge is looked at on a project it should be supplied and operated by a factory representative. This will insure that the gauge is in good working condition and is being operated properly.

3) The department should keep abreast of changes and advances in technology with regards to nuclear density gauges. In particular gauges which are capable of reading densities on thin layers of asphalt concrete, 1" to 1.5" in thickness.

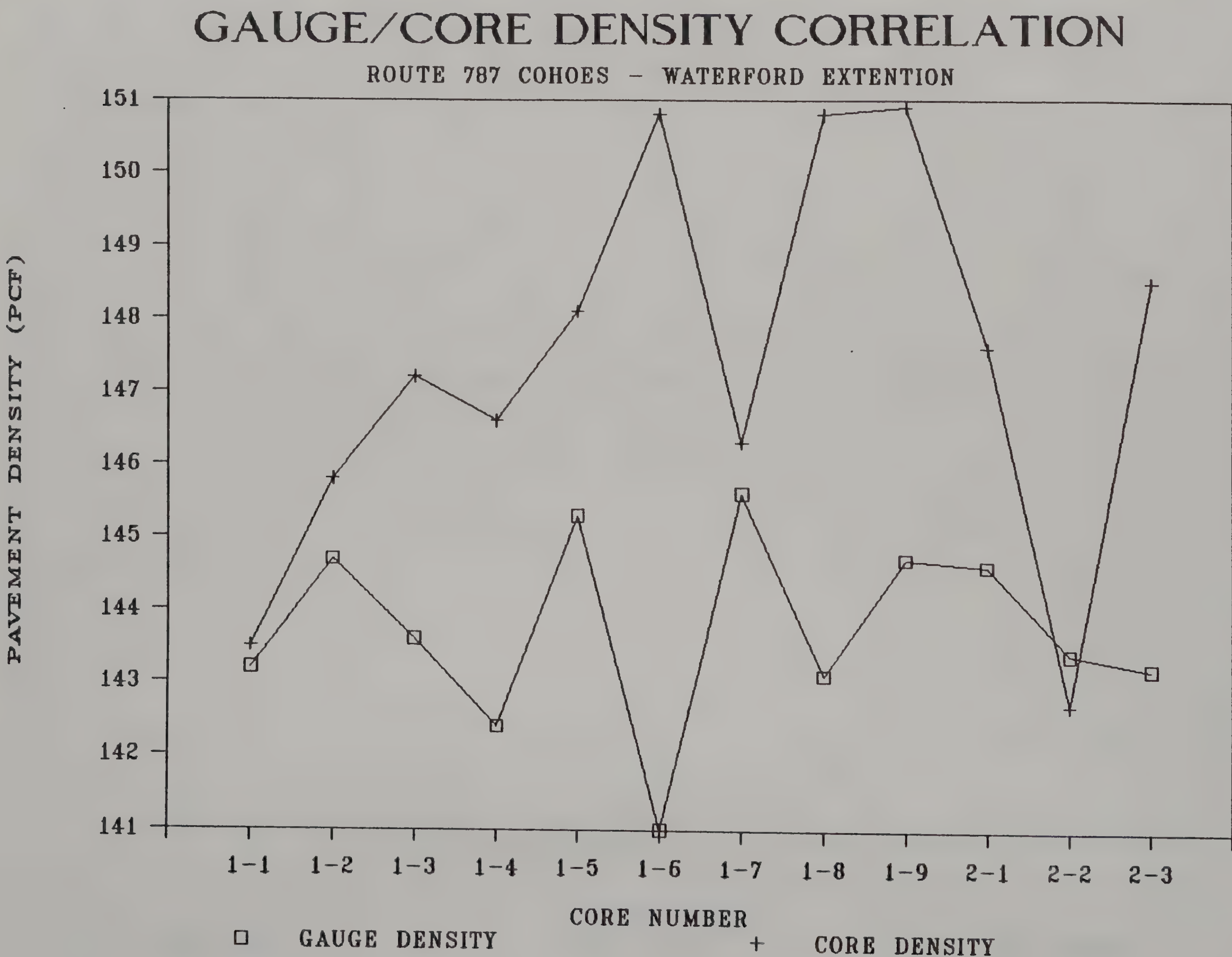
# T A B L E I

| CORE NO | GAUGE RESULTS: ONE MINUTE GAUGE READINGS | | | | AVG DENSITY | (DESIGN) Gmm | (%) AIR VOIDS | CORE RESULTS: CORE DENSITY | (RICE) Gmm | (%) AIR VOIDS | (INCHES) CORE HT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-1 | 141.8 | 142.4 | 143.0 | 145.6 | 143.2 | 2.498 | 8.1 | 143.5 | 2.520 | 8.7 | 0.875 |
| 1-2 | * | * | * | * | 144.7 | 2.498 | 7.2 | 145.8 | 2.490 | 6.0 | 1.250 |
| 1-3 | 141.0 | 142.8 | 142.8 | 147.8 | 143.6 | 2.498 | 7.9 | 147.2 | 2.490 | 5.2 | 1.250 |
| 1-4 | 139.4 | 143.1 | 143.3 | 143.6 | 142.4 | 2.498 | 8.6 | 146.6 | 2.480 | 5.4 | 1.625 |
| 1-5 | 142.2 | 145.4 | 146.0 | 147.4 | 145.3 | 2.498 | 6.8 | 148.1 | 2.500 | 4.9 | 1.625 |
| 1-6 | 138.8 | 141.0 | 141.3 | 142.7 | 141.0 | 2.498 | 9.5 | 150.8 | 2.490 | 2.8 | 1.250 |
| 1-7 | 143.8 | 144.1 | 146.2 | 148.3 | 145.6 | 2.498 | 6.6 | 146.3 | 2.500 | 6.1 | 1.625 |
| 1-8 | 140.7 | 141.3 | 144.4 | 146.2 | 143.1 | 2.498 | 8.2 | 150.8 | 2.480 | 2.7 | 1.500 |
| 1-9 | 143.8 | 143.9 | 145.3 | 146.0 | 144.7 | 2.498 | 7.2 | 150.9 | 2.540 | 4.9 | 1.625 |
| 2-1 | 143.3 | 143.9 | 145.0 | 146.2 | 144.6 | 2.498 | 7.2 | 147.6 | 2.500 | 5.4 | 1.500 |
| 2-2 | 140.9 | 142.7 | 144.2 | 145.7 | 143.4 | 2.498 | 8.0 | 142.7 | 2.520 | 9.4 | 1.500 |
| 2-3 | 142.5 | 142.8 | 143.0 | 144.5 | 143.2 | 2.498 | 8.1 | 148.5 | 2.510 | 5.4 | 1.375 |
| AVG | 141.7 | 143.0 | 144.0 | 145.8 | 143.7 | 2.498 | 7.8 | 147.4 | 2.502 | 5.6 | 1.417 |

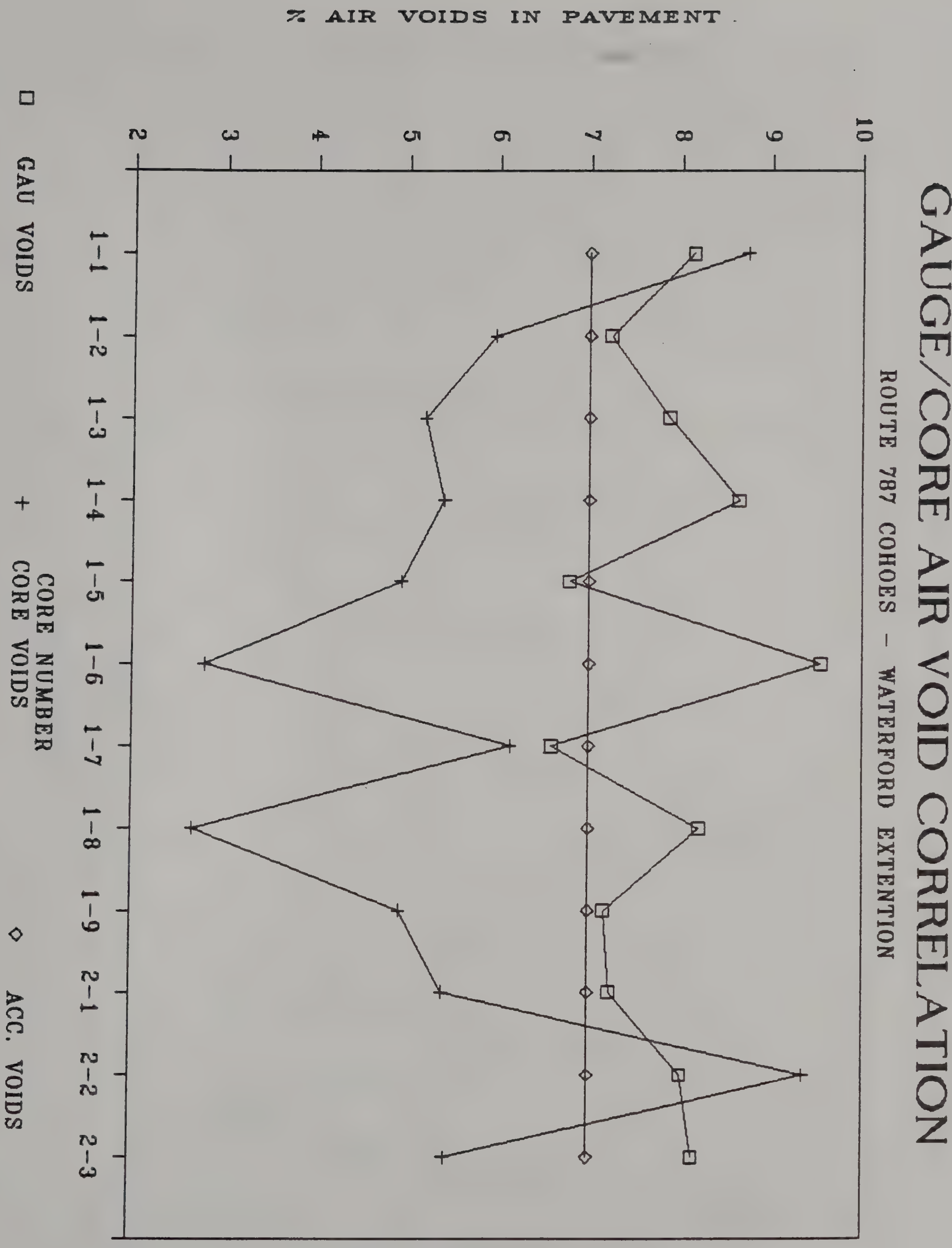
# T A B L E II

| CORE NO | 6-27-88 TESTING ONE MINUTE GAUGE READINGS | | | | AVG DENSITY | 6-28-88 TESTING ONE MINUTE GAUGE READINGS | | | | AVG DENSITY |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-2 | * | * | * | * | 144.6 | 146.8 | 146.3 | 148.3 | 144.2 | 146.4 |
| 1-4 | 139.4 | 143.6 | 143.1 | 143.3 | 142.4 | 145.7 | 140.1 | 143.1 | 142.7 | 142.9 |
| 1-7 | 144.1 | 146.2 | 148.3 | 143.8 | 145.6 | 146.3 | 145.7 | 146.3 | 146.3 | 146.2 |
| AVG | | | | | 144.2 | | | | | 145.2 |

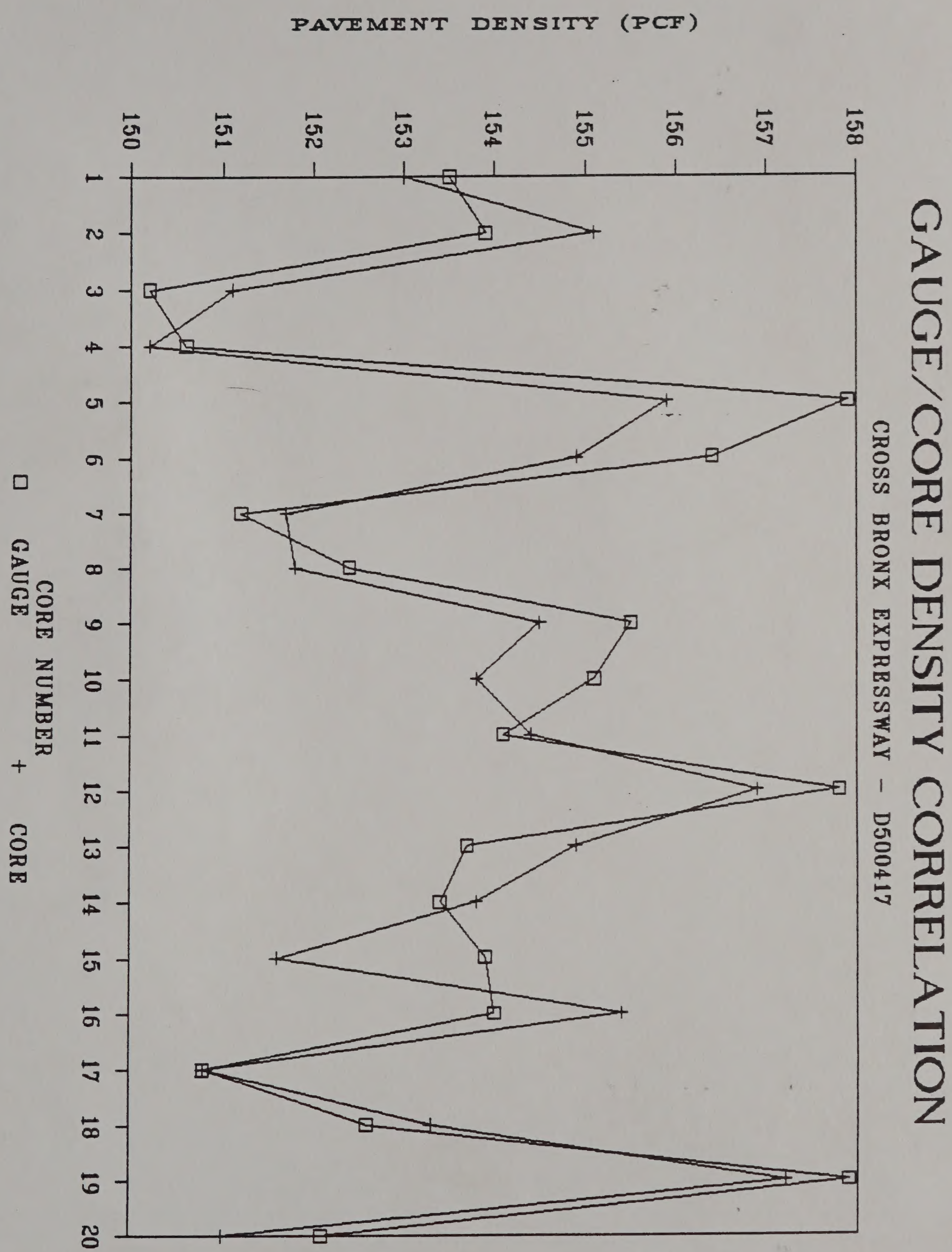
* - Four one minute readings averaged automatically by the gauge


GAUGE/CORE DENSITY CORRELATION
ROUTE 787 COHOES - WATERFORD EXTENTION
PAVEMENT DENSITY (PCF)
151
150
149
148
147
146
145
144
143
142
141
1-1
1-2
1-3
1-4
1-5
1-6
1-7
1-8
1-9
2-1
2-2
2-3
CORE NUMBER
□ GAUGE DENSITY
+ CORE DENSITY

GRAPH I


GAUGE/CORE AIR VOID CORRELATION
ROUTE 787 COHOES - WATERFORD EXTENTION
% AIR VOIDS IN PAVEMENT
10
9
8
7
6
5
4
3
2
1-1
1-2
1-3
1-4
1-5
1-6
1-7
1-8
1-9
2-1
2-2
2-3
CORE NUMBER
GAU VOIDS
CORE VOIDS
ACC. VOIDS

GRAPH II


GAUGE/CORE DENSITY CORRELATION
CROSS BRONX EXPRESSWAY - D500417
PAVEMENT DENSITY (PCF)
150
151
152
153
154
155
156
157
158
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
CORE NUMBER
□ GAUGE
+ CORE

GRAPH III